EXAMINING VOLCANIC TERRAINS USING IN SITU GEOCHEMICAL TECHNOLOGIES; IMPLICATIONS FOR PLANETARY FIELD GEOLOGY.

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Introduction: Regardless of the target destination for the next manned planetary mission, the crew will require technology with which to select samples for return to Earth. The six Apollo lunar surface missions crews had only the tools to enable them to physically pick samples up off the surface or from a boulder and store those samples for return to the Lunar Module and eventually to Earth. Sample characterization was dependent upon visual inspection and relied upon their extensive geology training. In the four decades since Apollo however, great advances have been made in traditionally laboratory-based instrument technologies that enable miniaturization to a field-portable configuration. The implications of these advancements extend past traditional terrestrial field geology and into planetary surface exploration.

With tools that will allow for real-time geochemical analysis, an astronaut can better develop a series of working hypotheses that are testable during surface science operations. One such technology is x-ray fluorescence (XRF). Traditionally used in a laboratory configuration, these instruments have now been developed and marketed commercially in a field-portable mode. We examine this technology in the context of geologic sample analysis and discuss current and future plans for instrument deployment.

We also discuss the development of the Chromatic Mineral Identification and Surface Texture (CMIST) instrument at the NASA Goddard Space Flight Center (GSFC). Testing is taking place in conjunction with the RIS4E (Remote, In Situ, and Synchrotron Studies for Science and Exploration) SSERVI (Solar System Exploration and Research Virtual Institute) team activities, including field testing at Kilauea Volcano, HI [1].

Overview of Handheld X-Ray Fluorescence (hXRF) Technology: Laboratory-based x-ray fluorescence technology has been used for decades to investigate the geochemistry of rock samples [2, 3]. Recently, however, this technology has been miniaturized by companies such as Bruker, Innov-X, ThermoScientific, etc. Though these instruments are developed and marketed for use in mining and industry, they have also begun to be applied to scientific problems. All hXRF data presented in this study were collected using an Innov-X hXRF unit that we calibrated using a suite of terrestrial basaltic standards (on loan from the Spectroscopy and Magnetics Lab run by Dr. Richard Morris at the NASA Johnson Space Center) [4, 5, 6].

Desert RATS 2010 Follow-up: The 2010 Desert RATS (Research and Technology Studies) field test involved two rovers (each rover was crewed by one astronaut and one field geologist) traversing a field area in the San Francisco Volcanic Field (SFVF). Each 2-person crew lived and worked in the rover for one week, investigating a series of volcanic features found near SP Crater, north of Flagstaff, AZ. Daily operations included a series of extravehicular activities (EVAs) designed for sample collection in the SFVF. The crews were supported by a science backroom that was following their updates through video and audio footage as well as intermittent communication with the crews [7]. While the hXRF was not integrated into the EVA operations during the mission, we have since analyzed many of the samples collected during week 2 of Desert RATS 2010 with the Innov-X hXRF unit [4].

Preliminary geologic mapping was completed for traverse and science planning purposes based on aerial imagery obtained of the site [8]. Many test hypotheses involved the relationship between individual lava flows and their source regions. With the exception of the flow emanating from SP crater, nothing but relative flow ages had been determined, and there were several flows in the test area where even relative ages or possible linkages could not be determined due to weathering and vegetation growth.

Handheld XRF data collected from the RATS 2010 samples show three distinct geochemical groups. One corresponds to the SP flow, which is visually very distinct and can be easily distinguished in the field. The other two groups, however, were not easily identifiable in hand sample, yet are clearly quite different from one another geochemically (ex. Figure 1, [4]). These two units were not identified real-time by the Desert RATS crews or the supporting science team, highlighting the need for the inclusion of handheld geochemical technology like the hXRF into both planetary analog missions and eventual crewed planetary exploration missions. More work is needed, however, to determine exactly what technologies should be included in this future instrumentation suite.

To investigate which technologies will be the most useful to an astronaut crew as well as how the

integration of this suite would impact surface operations, the RIS4E SSERVI team is completing a series of field activities in both Hawai'i and New Mexico designed to evaluate instrument integration in fieldwork.

RIS4E in Hawai'i: The RIS4E team completed two weeks of fieldwork at the December 1974 flow in the SW rift zone at Kilauea Volcano, HI, in September 2014. This trip was the first of five designed to test a series of in situ technologies for planetary surface exploration. Instruments tested in the 2014 field test included multispectral TIR, LiDAR, GPR, and differential GPS units. The field team was split into two teams, the structural/geophysical team and the geochemistry/mineralogy team. Fieldwork goals included investigating the flow's topography and subsurface structure as well as characterizing its geochemistry and mineralogy in situ. While the team was unable to bring a hXRF unit in the field in 2014, work is currently underway to collect hXRF data on samples collected from the December 1974 flow in order to both study its geochemistry as well as to further evaluate the utility of the hXRF in examining lava flows to aid in sample high-grading.

Developing CMIST: In conjunction with the ongoing RIS4E field efforts and hXRF analyses, we are working to develop a field portable instrument that combines x-ray fluorescence and x-ray diffraction technology to obtain a real-time look at both the chemistry and structure of a sample in situ [9]. The CMIST instrument is currently under development at the Goddard Space Flight Center and while it is not currently field portable, we are working to collect data on RIS4E HI samples in its benchtop configuration. This instrument shows great promise in being able to enhance geologic surface operations and give crews a better real-time understanding of the geologic history of an area of interest.

Conclusions and Moving Forward: Efforts in developing a suite of field portable instrumentation for planetary field geology are still ongoing. We will present data from both the hXRF and from CMIST as well as give preliminary results on geochemical data from the December 1974 flow. Additionally, initial field testing indicated that the multispectral TIR greatly enhanced the contextual awareness of the field team as data were processed. For instance, remote sensing data of the field area indicated that there were four local lithologies: a young volcanic unit, an older, volcanic unit, an ash unit, and a sand unit. The field TIR data, however, indicated more variability in the ash unit and the volcanic units that were not visible to the field team or identified using the remote sensing data, thus informing sample collection [10]. These results highlight the need for these technologies and indicate that future evaluation and field deployments are needed.

It is probable that the combination of instruments like the multispectral TIR and CMIST/hXRF will give field teams greatly increased geologic awareness, but at what cost? Will the time is takes for an astronaut to deploy the instrument and collect and synthesize the data be worth the scientific and operational return in a mission setting, or is an Apollo-style suite of instruments designed instead to only focus on sampling the better route to pursue? We explore these issues in this presentation and in future RIS4E field activities.

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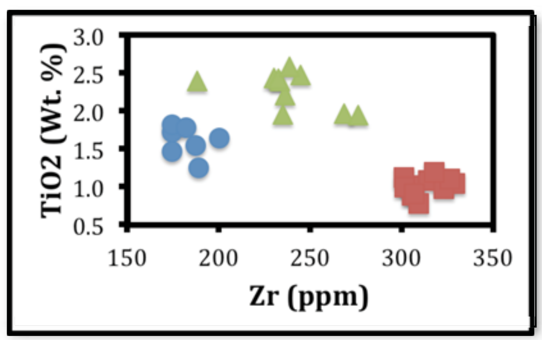

Figure 1: hXRF data collected on Desert RATS 2010 samples from the SFVF, AZ. The blue circles represent samples taken from the SP Crater flow, which was visually very distinct from the other local flows. The samples represented by the green triangles and red squares, however, were not distinguishable in the field in hand sample, highlighting the utility of employing field portable geochemical instrumentation.